CHAPTER 21

NATURAL REGENERATION

The purpose of this chapter is to:

- Classify, define, characterize, and contrast natural regeneration methods and associated silvicultural systems that are commonly applied and generally accepted for the management of major forest cover types in Wisconsin.
- Identify forest cover types where each method/system is commonly applied.
- Clarify silvicultural terminology.

A ***silvicultural system*** is a planned program of vegetation treatment during the entire life of a stand. All silvicultural systems include three basic component treatments: tending, harvesting, and regeneration. Typically, silvicultural systems are named after the stand age class structure and the regeneration method employed (e.g. even-aged uniform shelterwood system).

Tending refers to treatment of the stand during the time period between stand origin and final harvest (intermediate treatments include pruning, release, improvement, thinning, and salvage). Not all managed stands require tending treatments.

Harvesting (logging) refers to the process of gathering a timber crop. It includes felling, skidding/forwarding, on-site processing, and removal of products from the site. *Cutting* (as part of logging) is the felling of trees or stands. *Harvest cutting* is an intermediate or final cutting that extracts salable trees. A *harvesting method* is a procedure by which a stand is logged, where emphasis is on meeting logging requirements while concurrently attaining silvicultural objectives.

Several terms are commonly used ambiguously when referring to forest management. In common usage, *cutting methods* are techniques for selecting which trees to cut. *Clearcutting* is the removal in one operation of essentially all the trees in a stand. *Partial or selective cutting* is the removal of only a portion of the trees in a stand. Used in this context, these cutting methods do not necessarily refer to a natural regeneration method (see unsustainable cutting methods discussion on page 21-20). In this chapter, the terms clearcut and selection refer to specific planned natural regeneration methods.

Regeneration (reproduction) refers to the seedlings or saplings existing in a stand. In silviculture, it is the act of renewing tree cover by establishing young trees naturally or artificially. *Natural regeneration* is the establishment of young trees through natural seeding, sprouting, suckering, or layering. *Artificial regeneration* is the establishment of young trees through planting or direct seeding (Chapter 22).

A ***regeneration method*** is a procedure by which a stand is established or renewed by means of natural or artificial reproduction. The various methods include the removal of the old stand (usually involving a harvest), the establishment of a new one, and any supplementary treatments of vegetation, slash, or soil that are applied to create conditions favorable to the establishment of reproduction. A *regeneration cutting* is any removal of trees intended to assist regeneration already present or to make regeneration possible.

Stand age structure is an important characteristic used to characterize and classify stands and silvicultural systems. The three basic classified age structures are:

- *Even-aged*: A stand where the trees have only small differences in their ages (a single age class). By convention, the spread of ages does not differ by more than 20% of the intended rotation.
- *Two-aged*: A stand with trees of two distinct age classes, separated in age by more than 20% of rotation.
- *Uneven-aged*: A stand where the trees differ markedly in their ages, with trees of three or more distinct age classes either mixed or in small groups.

Silvicultural systems and regeneration methods can be classified in order to systematize the description of the wide variety of procedures used in practice. *The following stand level (> 2 acres) classification of* **planned natural regeneration methods** *is based on the mode of origin of regeneration and on the arrangement of cuttings in space and time*. Gradations and hybrids between methods are inherent to the classification. Reserve trees can be included with any of the following methods (see reserve tree discussion on page 21-18).

1. **Coppice**
   a. Simple Coppice
   b. Coppice with Standards
   c. Compound Coppice

2. **Clearcut**
   a. Uniform Clearcut
   b. Alternate (strip, patch) Clearcut
   c. Progressive (strip, patch) Clearcut

3. **Seed Tree**
   a. Single Seed Tree
   b. Group Seed Tree

4. **Overstory Removal**

5. **Shelterwood**
   a. Uniform Shelterwood
   b. Strip Shelterwood
   c. Group Shelterwood

6. **Selection**
   a. Single-Tree Selection
   b. Group Selection

The cover type chapters can be referenced for specific recommended regeneration methods and silvicultural systems. In general, the discussion of regeneration methods assumes that the stand management objectives include maintaining the current cover type, regenerating the stand promptly following harvest, and promoting stand vigor and health. When interpreting natural regeneration methods to encourage cover type conversion, refer to the guidelines for the target cover type; an adequate seed source or sprout/sucker stock must be available. When managing mixed stands, refer to guidelines for each individual cover type and adapt techniques that will facilitate each, either in patches or intermingled. Following the implementation of a regeneration method, it is necessary to assess the adequacy of regeneration and to determine the need for additional treatments.

In application, silvicultural systems are developed based predominantly on consideration of the silvical characteristics of the forest cover type, site potentials, and landowner goals. Stands and sites tend to be heterogeneous units and require adaptive interpretation and management. As stand and site characteristics vary, so do current management alternatives and potentials to meet different management objectives. General methods and systems can provide a guide to the development of stand level prescriptions, but must be sufficiently flexible to respond to variable stand and site conditions and to facilitate adaptive silviculture to meet landowner goals and objectives.

Coppice Method

A. Definition and Description

A silvicultural method designed to naturally regenerate a stand using vegetative reproduction. Stump or root sprouts form the majority of the new stand although some seed origin reproduction may be present.

B. Characteristics

- The basic method results in even-aged stands; however, the variations can result in two-aged or multi-aged stands.
- Vegetative reproduction (low forest)
- Reproduction from stump sprouts or root suckers
- Potentially applicable to most hardwood species
- New stand regenerates after the existing stand is harvested

C. Contrast With Other Methods

Differs from other even-aged regeneration methods (seed tree, shelterwood, overstory removal, and clearcut) in that the regenerated stand is derived from vegetative reproduction rather than a seed source. Generally, there is no residual stand left as the residual can interfere with regeneration and is not necessary to shelter the regenerated stand. It differs from selection in that it is an even-aged system and the reproduction is not from seed. The method somewhat mimics catastrophic loss and replacement of a stand, but differs in the amount and distribution of residual trees and coarse woody debris.

D. Variations to This Method

1. **Simple coppice:** A complete harvest is applied to the entire stand to be regenerated. This variation produces a stand similar in composition to the parent stand except that any conifer component will be reduced. Results in even-aged stand.
2. **Coppice with Standards:** A complete harvest is applied to the entire stand with the exception of chosen standards. The standards might be crop trees of the same species as the stand to be harvested but are often a different species. This variation can be used to slowly convert a stand to a different composition, to develop a seed-origin stand, or to manage mixed stands. It can result in a two-aged stand depending on the number of residual trees.
3. **Compound Coppice:** A modification of the coppice with standards method that incorporates two or more age classes of standards above the coppice stand. The age classes of the standards will be multiples of the rotation age of the coppiced stand. Results in two-aged or uneven-aged stand.

E. Application

Cover type specifics and applicability of the coppice method are addressed in appropriate cover type chapters of this Handbook. This method has potential to regenerate most hardwoods in Wisconsin. No Wisconsin conifers respond to this regeneration technique. In Wisconsin, the most common use of the coppice method is in regenerating the aspens. It also is a recognized method to regenerate scrub oak, red maple, and bottomland hardwoods. It may have potential for use in white birch, oak, black walnut, central hardwoods, northern hardwoods, and swamp hardwoods. This method does not apply to jack pine, red pine, white pine, hemlock-hardwood, fir-spruce, swamp conifer, black spruce, tamarack, or cedar.

General considerations in the application of the coppice method are:

- Spacing: For species reproducing from stump sprouts, spacing of the regenerated stand is determined by the spacing of the parent stand. For root suckering species, spacing of the parent stand is not as important of a factor.
- Sprouting capability: The vigor of the sprouting response varies with age and size of the parent trees. This response is species-specific and highly variable. In general, sprouting is most vigorous in trees that are experiencing their most rapid growth.
- Cutting season
- Site capability

- Competition
- Overstory composition, condition, and health

F. **Advantages and Disadvantages**

Advantages:
- Simple, dependable regeneration
- Efficiency of harvesting operations
- No site preparation is needed
- No delay in regeneration
- Growing space continuously occupied
- Longer time period between entries reduces some vehicle impacts to soils

Disadvantages:
- Spacing of stump sprouts may contribute to poorly-formed trees and an understocked stand
- Potential for water table changes on wet sites
- Higher windthrow potential (standards, adjacent stand)

G. **Figure 21-1.** Coppice with standards regeneration method

- aspen regeneration (one year following harvest) with red pine standards.

photo by Jeff Martin, J-Mar Photography

Clearcut Method

A. Definition and Description

A silvicultural method used to regenerate a stand by the removal of most or all woody vegetation during harvest creating a completely open area leading to the establishment of an even-aged stand. Regeneration can be from natural seeding from adjacent stands or from trees cut in the harvest operation. Regeneration is established during or following stand removal.

B. Characteristics

- Even-aged
- Seed origin (high forest)
- Used for shade intolerant, and exposure tolerant species
- New stand regenerates after the existing stand is harvested
- Best adapted for species that reproduce naturally after major disturbance

C. Contrast with Other Methods

Differs from seed tree and shelterwood regeneration methods in that no trees are left in the cut area for seeding purposes; rather, the seed source is from outside the cut area, or from the felled tops of harvested trees. Also, there is no overstory that offers protection to the regeneration. Differs from coppice in that regeneration in a clearcut is from seed. Unlike overstory removal, the regeneration in a clearcut is not present until after the harvest. Clearcut regeneration is even-aged, while that from the selection method is uneven-aged. This method partially simulates stand mortality due to major natural disturbance such as fire, but may be less patchy, removes all large wood, and produces different seedbed characteristics.

D. Variations to This Method

1. **Uniform Clearcut:** Entire stand is removed in one cut. Designed to regenerate the entire stand at the same time.

2. **Alternate Clearcut (strip or patch):** The stand is removed in two cuttings, occurring at separated periods in time. Generally, one half of the stand acreage is removed in each cutting. Cutting may be in patchwork design, or designated strips. The uncut area serves as a seed source. Stand removal is completed within a period of time, not exceeding 20% of intended rotation. The clearcut areas are best oriented so that they are at right angles to the direction of seed-dispersing winds.

3. **Progressive clearcut (strip or patch):** The stand is removed as above, except using a series of strips or patches harvested over three or more entries, usually covering an equal area on each occasion. The stand is removed within a period of time not exceeding 20% of intended rotation. In higher watertable areas, this method may be chosen to reduce water fluctuations and reduce windthrow. In steeply sloping areas, this method may reduce erosion and windthrow.

E. Application

Cover type specifics and applicability of the clearcut method are addressed in appropriate cover type chapters of this Handbook. The clearcut method is a recognized method to regenerate jack pine, white birch, scrub oak, oak, fir-spruce, swamp conifer, black spruce, tamarack, and cedar cover types. It may have potential for use in regenerating aspen, black walnut, central hardwood, and bottomland hardwood cover types. This method does not apply to red pine, white pine, red maple, northern hardwood, hemlock-hardwood, or swamp hardwood.

General considerations in the application of the clearcut method are:

- Seeding characteristics of desired species: maturation, viability, dispersal, germination, good seed crop
- Site capability
- Seed/seedling needs for establishment and survival
- Site preparation
- Existing and potential competition

F. **Advantages and Disadvantages**

Advantages:
- Local, known seed source which is adapted to the site
- Efficiency of harvesting operations
- No preparatory harvest is necessary
- Maintenance of shade-intolerant species in the landscape
- Complete overstory removal can result in dense stocking and vigorous regeneration and growth for many species
- Logistically easier to treat the site to control undesirable vegetation
- Longer time period between entries reduces some vehicle impacts to soils

Disadvantages:
- Timing relative to good seed years is difficult
- Coppice regeneration of unwanted species may dominate the site
- Dispersal, density and spacing pattern of desirable seed may be unsatisfactory
- Overexposure may cause seedling failure
- If regeneration is unsuccessful, seed source can be lost in uniform clearcut
- May require noncommercial cutting and extensive site preparation
- On wet sites, can have potential for water table changes
- Higher windthrow potential (strips, patches, adjacent stand)

G. **Figure 21-2.** Clearcut regeneration method applied in jack pine

photos by Clair Merrit, Purdue Univ., forestryimages.org

Recent clearcut in jack pine.

Jack pine regeneration 8 years after clearcut.

Seed Tree Method

A. **Definition and Description:**

A silvicultural method designed to bring about reproduction on what are essentially clearcut harvest areas by leaving enough trees singly or in groups to naturally seed the area with adequate stocking of desired species in a reasonable period of time before the site is captured by undesirable vegetation. In this method only a few trees (typically 3 to 10 per acre) of the original stand are left, and this residual stocking is not sufficient to protect, modify, or shelter the site in any significant way. Seed trees may be removed after establishment or left indefinitely.

B. **Characteristics**

- Even-aged
- Seed origin (high forest)
- Overstory does not significantly modify understory conditions
- Removal of overstory after establishment is optional
- Residual trees provide most of the seed to regenerate the site

C. **Contrast with Other Methods**

Differs from coppice regeneration methods in that regeneration comes primarily from seed rather than vegetatively. It differs from clearcuts in that the seed source for regeneration comes from residual trees within the harvest area rather than outside the cut area or relying on seed existing on or in the ground. It differs from a shelterwood in that the residual stocking is too sparse to modify the understory environment for seedling protection. Seed tree differs from overstory removal in that regeneration is not present before the stand is harvested. It differs from the selection method in that the regeneration is even-aged. The system mimics severe natural catastrophic events like wind or fire where only a few individual trees survive to propagate, however, most large wood is removed and seedbed characteristics are different from those created by natural disturbance.

D. **Variations to This Method**

1. **Single Tree**: The distribution of individual seed trees, typically 3 to 10 per acre, is fairly uniform across the stand.

2. **Group Seed Tree**: Clusters of seed trees are left as groups or strips distributed across the stand, but not exceeding 10% of normal full stocking level.

E. **Application**

Cover type specifics and applicability of seed tree method are addressed in appropriate cover type chapters of this Handbook. The seed tree method is a recognized method to regenerate white pine and jack pine. It may have potential to regenerate red pine, white birch, scrub oak, oak, fir-spruce, swamp conifer, black spruce, tamarack, and cedar. This method does not apply to aspen, black walnut, red maple, central hardwood, northern hardwood, hemlock-hardwood, bottomland hardwood, or swamp hardwood cover types.

General considerations in application of seed tree method are:

- Seeding characteristics of desired species: maturation, viability, dispersal, germination, good seed crop
- Desired number of seed trees
- Site capability
- Seed/seedling needs for establishment and survival
- Site preparation
- Existing and potential competition
- Overstory composition, condition, and health

F. **Advantages and Disadvantages**

Advantages:
- Local seed source
- Efficiency of harvesting operations
- No preparatory harvest is necessary
- Seed source maintained in case of initial failure
- Fairly easy to treat the site to control undesirable vegetation
- Longer time period between entries reduces impacts to soils

Disadvantages:
- Potential loss of residual to wind and other environmental conditions
- Techniques of application are not well-developed for every species
- Timing relative to good seed crop difficult
- Residual trees may interfere with growth of new crop
- Added time for marking seed trees
- Regeneration density may be uneven
- May involve site preparation: chemical, scarification or prescribed burning
- On wet sites, can have potential for water table changes

G. **Figure 21-3.** Pine regeneration following application of the seed tree regeneration method.

computer image by Andrew Stoltman, Univ. Wisc., Dept. For. Ecol. & Mgmt., Madison

Overstory Removal Method

A. **Definition and Description**

A silvicultural method in which the entire stand overstory is removed in one cut to provide release of established seedlings and saplings. This method has also been referred to as a natural shelterwood or a one-cut shelterwood.

B. **Characteristics**

- Even-aged
- Seed origin (high forest)
- Release of established natural regeneration
- Overstory inhibits advancement of seedlings and saplings
- Overstory may be low or high quality
- Used for shade tolerant, mid-tolerant and intolerant species
- Often used for species conversion or quality improvement

C. **Contrast with Other Methods**

Overstory removal results in an even-aged stand structure as opposed to uneven-aged. It differs from the clearcut and the coppice regeneration methods in that seedling and sapling regeneration is established prior to overstory removal. It differs from the shelterwood and seed tree methods in that no manipulation of the overstory is needed to establish regeneration. This method mimics natural deterioration of the overstory, but at an accelerated rate, with the entire overstory removed at the same time, and most coarse woody debris removed.

D. **Variations to This Method:** None

E. **Application**

Cover type specifics and applicability of overstory removal are addressed in appropriate cover type chapters of this Handbook. Overstory removal can be applied to any cover type if adequate advanced regeneration is established.

General considerations in the application of the overstory removal method are:

- Overstory health, condition and composition
- Gradual or patch overstory removal may be necessary on wet sites to reduce the chance of raising the water table, causing damage or mortality to regeneration
- Adequate stocking, distribution, vigor, and desirability of established, advanced regeneration
- Protection of regeneration from harvest damage
- Site capability
- Existing and potential competition

F. **Advantages and Disadvantages**

Advantages:
- Relatively simple to establish the timber sale
- Local seed source
- Site preparation is not needed
- Advancement of established and acceptable seedling population adapted to the site
- Resprouting ability of damaged hardwood regeneration
- No delay in regeneration; growing space continuously occupied

Disadvantages:
- Inability of conifer regeneration to resprout following damage
- Careful harvesting to minimize damage to the new stand will be needed

G. **Figure 21-4.** Even-aged overstory removal regeneration method.

The original stand with well established advanced regeneration. The stand may have been unmanaged or previously thinned, but no targeted regeneration techniques have been applied.

The entire stand overstory has been removed in one cut to provide release of the established seedlings and saplings.

Shelterwood Method

A. Definition and Description

A silvicultural method used to regenerate a stand by manipulating the overstory and understory to create conditions favorable for the establishment and survival of desirable tree species. The method is designed to regenerate an even-aged stand and normally involves removal of most of the overstory in two or more subsequent cuttings after the new stand is established. The overstory serves to modify understory conditions, create a favorable environment for reproduction, and provide a seed source. A secondary function of the overstory is to allow further development of quality overstory stems during seedling establishment to increase the efficient use of growing stock. The system is characterized by a preparatory cut (optional), seeding cut(s), and overstory removal. The most vigorous trees are normally left and less vigorous trees removed.

B. Characteristics

- Even-aged
- Seed origin (high forest)
- Overstory modifies understory conditions - protects natural reproduction
- Overstory is removed only after regeneration established
- Method allows for variations in regeneration over space and time
- Overstory generally provides most seed

C. Contrast with Other Methods

Initial shelterwood cuttings usually resemble heavy thinnings. Natural reproduction starts under the protection of the older stand and is finally released when it becomes desirable to give the new stand full use of the growing space. This method differs from uneven-aged, selection methods in that it promotes an even-aged stand structure. It differs from clearcutting and coppice methods in that the next stand is established on the site prior to overstory removal. Shelterwood differs from seed tree cutting in that the overstory serves to protect the understory as well as distributing seed. The system partly mimics natural deterioration of the overstory, only at an accelerated rate, but is dissimilar because most coarse woody debris is removed.

D. Variations to This Method

1. **Uniform Shelterwood:** A shelterwood method applied to the entire stand, designed to regenerate the entire stand at the same time.
2. **Strip Shelterwood:** A shelterwood method in which the stand is regenerated in strips progressing across the stand over a period of time. Cutting is concentrated in certain strips while the rest of the stand remains temporarily unharvested.
3. **Group Shelterwood:** A shelterwood method in which the stand is regenerated using patches of existing desirable regeneration which are gradually enlarged over time through overstory and understory manipulation adjacent to these patches. Patches of regeneration are often the result of natural disturbance or prior cutting. In the absence of existing regeneration, stand manipulation can occur to cause reproduction to become established.

E. Application

Cover type specifics and applicability of the shelterwood method are addressed in appropriate cover type chapters of this Handbook. The shelterwood method is a recognized method to regenerate the white pine, white birch, scrub oak, oak, red maple, central hardwood, northern hardwood, hemlock-hardwood, fir-spruce, swamp conifer, black spruce, cedar, swamp hardwood, and bottomland hardwood forest cover types. The shelterwood method may have potential for use in regenerating jack pine, red pine, black walnut, and tamarack. This method does not apply to aspen.

General considerations in the application of the shelterwood method are:

- Site evaluation (suitable to meet nutrient-moisture needs of species)
- Level/intensity of competition
- Overstory condition, health, and composition

- Seed tree condition, health, and composition (form, crown class, seeding potential, age)
- Determination of existing stand maturity
- Evaluation of existing reproduction
- May involve a preparatory cut
- Conduct seeding cut - allow stand to develop
- Seedbed preparation
- Control competition during good seed year (fire, mechanical, chemical)
- Monitor understory development
- Conduct removal cut

F. **Advantages and Disadvantages**

Advantages:
- Local, known seed source
- High seedling numbers
- Higher seedling/stand diversity
- Can be repeated if unsuccessful
- Reproduction generally more certain and complete than clearcutting or seed tree
- Overstory develops more rapidly and achieves larger size

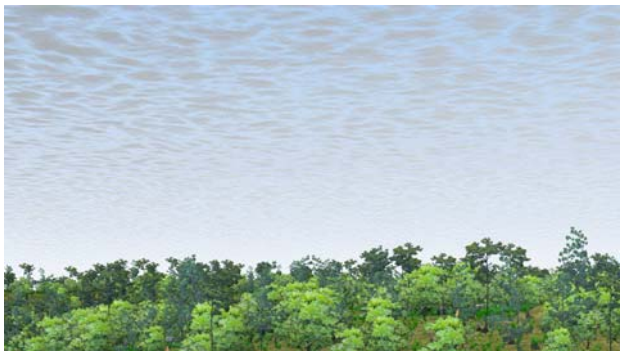
Disadvantages:
- Techniques of application are not well-developed for every species
- Requires technical skill to apply this method
- May involve chemical use, scarification, noncommercial cutting or prescribed burning.
- More careful logging practices often required in overstory removal to protect understory.
- Seed or preparatory cuts may require care
- Timing to seed crop
- Added time for timber sale establishment

G. **Figure 21-5.** Even-aged uniform shelterwood regeneration method.

An even-aged sawtimber hardwood stand near rotation age.

The same stand soon after a shelterwood seeding cut to encourage oak reproduction.

Five years later, the advanced regeneration is becoming well established.



The overstory has been removed to release the young oak stand and provide free-to-grow conditions. At this stage, full sunlight optimizes growth and vigor.

computer images by Andrew Stoltman,
Univ. Wisc., Dept. For. Ecol. & Mgmt., Madison

Selection Method

A. Definition and Description

A silvicultural method designed to regenerate and maintain uneven-aged stands by removing some trees at regular intervals. Trees are removed in various size classes, either singly or in small groups. An uneven-aged stand is maintained by periodically regenerating new age classes while manipulating the overstory structure to facilitate continual development of quality growing stock. Stand regeneration is achieved by periodically manipulating the overstory and understory to create conditions favorable for the establishment and survival of desirable tree species. Regeneration cuts, thinning, and harvesting usually occur simultaneously. Generally, most regeneration is seed origin (high forest method), although a component can be vegetative.

B. Characteristics

- Uneven-aged
- Seed origin (high forest)
- Overstory never completely removed – periodic removal of individuals and groups of overstory trees to recruit new overstory trees and regeneration
- Overstory provides a seed source, and modifies understory conditions to create a favorable environment for the reproduction, competition, and growth of certain species
- Favors regeneration and maintenance of shade tolerant species; variations can favor mid-tolerants
- Method allows for variations in regeneration and structure (e.g. age class, composition, density) over space and time
- Regeneration cuts (gap creation), thinning, and harvesting usually occur simultaneously

C. Contrast with Other Methods

The selection regeneration method is utilized to develop and maintain uneven-aged stands, whereas the other five major methods are all even-aged. Residual stand stocking is at a specified level to promote development of quality boles and fully utilize the site. Natural reproduction is established and develops in association with a permanent multiaged overstory. The overstory serves to distribute seed and modify understory conditions, favoring the maintenance of shade tolerant and mid-tolerant species. The selection method resembles a thinning, but regeneration is facilitated through consideration of species regeneration requirements and gap creation. This method simulates natural mortality and disturbance (e.g. senescence and low to moderate intensity windthrow), but is more regulated and homogeneous, impacts younger stands, and removes most coarse woody debris.

D. Variations to This Method

1. **Single-tree selection:** Individual trees of various size and age classes are periodically removed to provide space for regeneration and to promote growth of remaining trees. Each regeneration opening (gap) covers an area equivalent to the crown spread of a single large tree that has been removed. The spacing of regeneration gaps is irregular, based on the location of large harvested trees.
2. **Group selection:** Trees are periodically removed in small groups to create conditions favorable for the regeneration and establishment of new age classes. In general, the openings created may range in size from fairly small (30 foot diameter circle is 0.02 acres) up to about one-half acre (166 foot diameter circle, representing approximately two tree lengths). In northern hardwood management, gaps generally are less than 0.1 acres in size. Smaller openings favor the regeneration of more tolerant species, while larger openings favor mid-tolerants (and some intolerants). Spatial distribution of gaps may be irregular and dictated by small variations in stand conditions, such as the vigor, health, and size of individual and small groups of trees. The remainder of the stand is thinned.

E. Application

Cover type specifics and applicability of the selection method are addressed in appropriate cover type chapters of this Handbook. The single-tree selection method is a recognized method to regenerate the northern hardwood and hemlock-hardwood forest cover types, whereas the group selection method is appropriate for the red maple, central hardwood, northern hardwood, and bottomland hardwood cover types. The single-tree selection method may have potential for use in regenerating the central hardwood, fir-spruce, swamp conifer, black spruce, and cedar cover types, whereas the group selection method may have potential for white pine, scrub oak, oak, black walnut, hemlock-hardwood, fir-spruce, swamp conifer, black spruce, white cedar, and swamp hardwood cover types. Neither method is applicable to jack pine,

red pine, aspen, white birch, or tamarack. To convert even-aged stands to uneven-aged structure, several cutting cycles are needed to establish multiple age classes.

General considerations in the application of the selection method are:

- Site evaluation (suitable to meet moisture and nutrient demands of species)
- Stand composition, size and age class structure, condition, and health
- Potential seed and sprout sources – composition, condition, health
- Advanced regeneration
- Regeneration requirements (moisture, nutrients, light, heat) of desired species
- Competitive abilities of desired species, and potential levels of competition among species
- Seedbed preparation
- Competition control
- Overstory impacts on understory light and heat levels
- Gap management – smaller gaps favor shade tolerant species, and larger gaps favor mid-tolerants
  - > previous gaps needing expansion to release established regeneration
  - > number of new gaps to release advanced regeneration or establish new regeneration
  - > size and expected closure rates (crown expansion)
- Order of removal of overstory trees for gap creation, thinning, and harvest – generally the most vigorous crop trees are left, and less vigorous and diseased trees are removed
- Cutting cycle and allowable cut
- Protection (residual stems, crowns, root systems, advanced regeneration) from logging damage

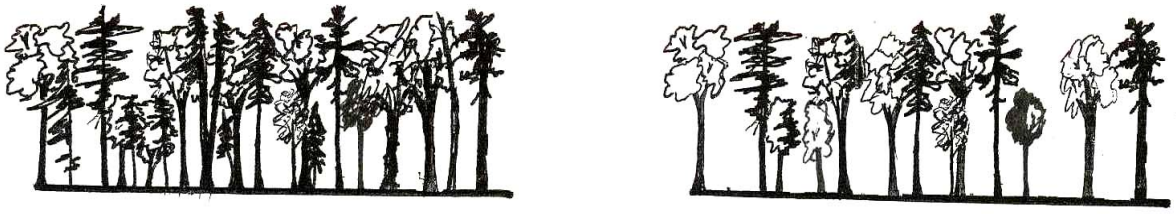
F. **Advantages and Disadvantages**

Advantages:
- Permanent forest with multiple age classes – the overstory is not completely removed
- Maintenance of a permanent overstory allows treatment adjustment and modification if problems arise or objectives are not initially achieved
- Relatively continuous full site occupancy
- Local, known seed source
- Reproduction relatively certain
- System favors shade tolerant species, and in some applications mid-tolerants
- For some species on some sites, there is little need for site preparation or competition control
- Periodic improvement of stand quality through judicious tending
- Maximizes growth and quality for some species (e.g. northern hardwoods)
- Can grow large, high quality trees – facilitates high levels of sawtimber production
- Periodic income can be relatively frequent (sustained yield)

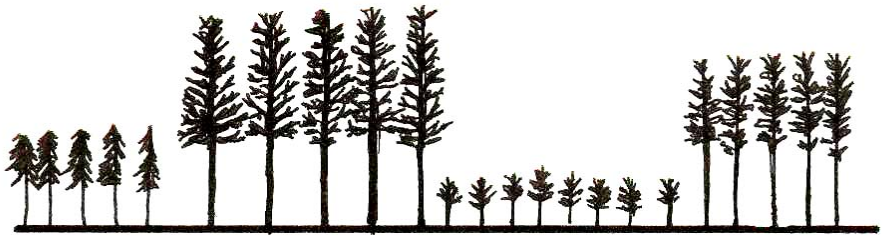
Disadvantages:
- Requires technical skill and need to monitor stand conditions
- Techniques of application are not well-developed for every species, especially the mid-tolerants
- Not a good system to regenerate and manage intolerants
- Species diversity can be difficult to establish or maintain
- For some species, may require timing to seed crop
- Some site preparation techniques not feasible
- May involve chemical use, scarification, noncommercial cutting, or prescribed burning
- Careful logging practices required to protect overstory and advanced regeneration; some damage is unavoidable
- Frequent reentry increases the frequency of site disturbance
- Frequent reentry requires a more extensive and permanent network of access roads and skid trails
- For any given entry, income is less than for complete overstory removal
- Added time and cost for timber sale establishment
- Logging costs are relatively high to remove scattered sawtimber trees

G. **Figures Demonstrating the Selection Regeneration Method**

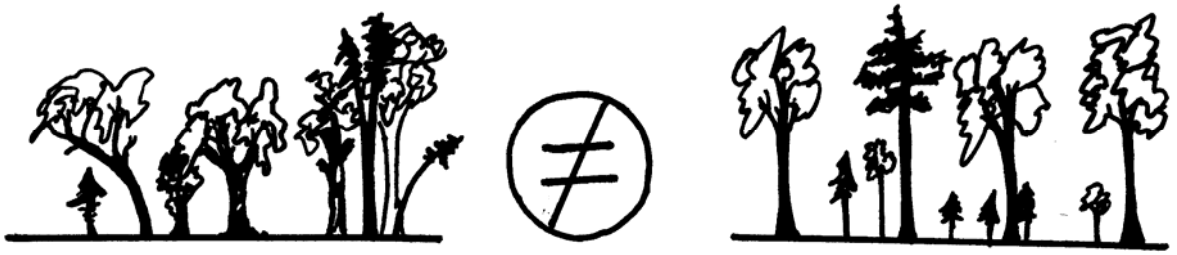
1. Figure 21-6. Single-tree selection – before and after cutting for harvest, thinning, and regeneration.



2. Figure 21-7. Group selection – within a regulated stand, four groups (patches) of different ages.



3. Figure 21-8. The high-grade selective cut is not the same as the selection regeneration method.



The high-grade selective cut removes the best trees and leaves low quality trees to predominate. This is not part of a silvicultural system.

Uneven-aged selection systems promote stand quality, tree quality and vigor, and targeted regeneration. Careful planning and implementation are required.

Table 21.1 Natural Regeneration Methods by Forest Cover Type for Wisconsin

FOREST COVER TYPES[1]	NATURAL REGENERATION METHODS						
	Coppice	Clearcut	Seed Tree	Overstory Removal	Shelterwood	Group Selection	Single-tree Selection
Jack Pine		GAP	GAP	GAP	X		
Red Pine			X	GAP	X		
White Pine			GAP	GAP	GAP	X	
Aspen	GAP	X		GAP			
White Birch	X	GAP[2]	X	GAP	GAP		
Scrub Oak	GAP	GAP	X	GAP	GAP	X	
Oak	X	GAP	X	GAP	GAP	X	
Black Walnut	X	X		GAP	X	X	
Red Maple	GAP			GAP	GAP	GAP	
Central Hardwood	X	X		GAP	GAP	GAP	X
Northern Hardwood	X			GAP	GAP	GAP	GAP
Hemlock-Hardwood				GAP	GAP	X	GAP
Fir-Spruce		GAP[2]	X	GAP	GAP	X	X
Swamp Conifer (Fir)		GAP[2]	X	GAP	GAP	X	X
Black Spruce		GAP[2]	X	GAP	GAP	X	X
Tamarack		GAP[2]	X	GAP	X		
Cedar		GAP[2]	X	GAP	GAP	X	X
Swamp Hardwood	X			GAP	GAP	X	
Bottomland Hardwood	GAP	X		GAP	GAP	GAP	

GAP (generally accepted practice): Method generally accepted in Wisconsin and supported by literature. Refer to appropriate cover type chapters for application details. The generally accepted methods may not be reflected in some cover type chapters that have not been updated recently.

X: Method may have potential for application

[1] Natural regeneration methods apply to the cover type to be regenerated, not necessarily the currently existing cover type.

[2] Strip clearcutting generally recommended

Reserve Trees

A. Definition and Description

Stand-level reserves are scattered, living individual trees and/or groups of trees left unharvested for reasons other than for the purpose of regeneration. Synonyms may include leave trees, green tree retention, and standards.

Reserves can be uniformly or irregularly distributed single trees, small tree clusters, large well-defined groups (usually <2 acres, based on DNR Recon protocol), or any mixture thereof. Reserve trees are not intended to provide any more than incidental seed or shelter to the regeneration stand and site. Reserve trees should not significantly inhibit the growth and vigor of most of the younger stand. Use of reserves can be compatible with any silvicultural system, under appropriate stand and site conditions. Resulting stands may become two-aged or tend towards an uneven-aged condition as a consequence of both an extended period of regeneration establishment and the retention of reserve trees that may represent one or more age classes.

B. Reasons for Reserves (Benefits)

1. Wildlife
   a. Den and nest trees
   b. Cover
   c. Food (foraging, hunting)
   d. Display locations
   e. Habitat diversity
   f. Travel corridor
   g. Protect areas of special concern (special habitat)
   h. Future coarse woody debris

2. Aesthetics
   a. Reduce unobstructed line of vision
   b. Break up “clearcut” look
   c. Provide diversity in future stand
   d. Retain visually unique trees

3. Timber Production

   a. Reserve high quality trees for future harvest

4. Water and Soil Quality

   a. Reduce run-off
   b. Reduce erosion
   c. Maintain water and nutrient cycles

5. Miscellaneous

   a. Protect cultural resources
   b. Buffer adjacent stands
   c. Landmarks, such as marker trees and witness trees

C. Potential Problems with Reserves

1. Susceptible to wind throw on wet or shallow soils, or for shallow rooted species
2. Susceptible to stem and crown damage during stand harvest
3. Susceptible to crown dieback and mortality following harvest
4. Increased potential for epicormic branching
5. Provide potential sites for pathogen breeding and maintenance
6. Damage to younger stand if reserves are harvested during mid-rotation

7. Reduced growth and vigor of regeneration occurring beneath reserves
8. Potential for increased predation of some wildlife

D. **Applications**

Reserve overstory trees will shade portions of a newly developing stand or patch. Increased numbers of reserve trees and trees with larger and denser crowns will cause more shading. Furthermore, reserve tree crowns can expand over time, increasing shading effects. Shading by reserve trees potentially can reduce growth within portions of newly developing established even-aged stands. The point at which growth reductions become significant depends on a variety of factors, including: stand management objectives (for reserve trees and young trees), growth rates and potential development (crown and bole) of reserve trees, growth rates and shade tolerance of species comprising the new stand, site quality, understory competition, and potential damaging agents. In most cases, to promote optimum growth of established even-aged stands of reproduction, (nearly) full sunlight generally is preferred. Under even-aged management systems, when objectives include the retention of reserve trees beyond the regeneration establishment phase, residual crown closures of <20% generally (for most species and conditions) will not significantly reduce vigor, growth, and development of the developing stand.

Use of reserves can be compatible with any silvicultural system, under appropriate stand and site conditions. All high forest (seed origin) planned natural regeneration methods have variants with reserves. Coppice-with-standards is the analogous low forest (vegetative reproduction) regeneration method. With reserves, even-aged systems can become two-aged systems, and two-aged systems can become uneven-aged systems.

1. Coppice-with-Standards: Some of the standards are retained after regeneration has become established to achieve objectives other than regeneration.

2. Clear Cut with Reserves: A clearcut in which some reserve trees are not harvested to attain objectives other than regeneration. Removal of all trees in a stand in a single operation except for some scattered individuals, or small groups, or a combination of both.

3. Seed Tree with Reserves: Some of the seed trees are retained after regeneration has become established to attain objectives other than regeneration.

4. Overstory Removal with Reserves: Some overstory trees are not removed, but are retained to achieve objectives other than regeneration.

5. Shelterwood with Reserves: Some of the shelter/seed trees are retained after regeneration has become established to achieve objectives other than regeneration.

6. Group Selection with Reserves: Individual trees or groups of trees are retained to achieve objectives other than regeneration.

7. Single Tree Selection with Reserves: Individual trees or groups of trees are retained to achieve objectives other than regeneration.

The characteristics of good reserve trees (e.g. species, life span, size, shape, colors, rooting, decay, mast, representation) are highly variable and depend on the intended benefits of the reserve trees (management objectives). Reserve trees may be intended for future harvest, or harvest may be foregone in order to accomplish other objectives. If reserve trees are to be harvested during future entries into the stand, then they are expected to continue to grow and to survive, so they should be relatively vigorous and low risk, and have a sufficiently long expected life span.

Practices Not Part of Silvicultural Systems That May Result in Natural Regeneration

A. **Unsustainable Cutting Methods**

Timber cutting methods are not necessarily tied to silvicultural systems. Sometimes, stand tending and regeneration are not adequately considered. In such cases, the lack of planning and foresight can result in stand degradation in terms of tree vigor and quality. Some examples of timber cutting methods not being part of silvicultural systems are:

1. *Economic clearcut*: A clearcut that does not include a plan for regeneration.

2. *High-grade selective cut*: A selective cut of the most valuable and highest quality trees, that leaves low value and quality trees to predominate.

3. *Diameter limit selective cut*: A selective cut of all trees greater than a certain diameter, where primary objectives do not include thinning to improve growth or quality, release of quality growing stock, or targeted quality regeneration.

These methods are often applied in an attempt to maximize short-term economic gain. In general, they do not represent sustainable forest management.

B. **Prescribed Catastrophic Fire**

Wildfire, or fire intentionally applied to the land to mimic wildfire, can regenerate some cover types, such as jack pine. This forest management method and regeneration alternative is not a silvicultural system, because it virtually eliminates current harvest opportunities.

C. **Passive Management**

Passive management is a deliberate decision to not manipulate the vegetation. It is a forest management system and regeneration alternative that does not conform to any silvicultural system, because of the lack of active treatment application.

Establishment and Evaluation of Adequate Natural Regeneration

The successful regeneration of forest stands is a critical part of all silvicultural systems. Detailed planning is necessary for successful targeted natural regeneration. There are several factors to consider in the planning process, including:

- management objectives,
- intrinsic site factors and variation (e.g. habitat type, soil, geology, physiography, site index, microsites),
- current stand composition, structure, and health (overstory and understory),
- natural dynamics (succession and disturbance),
- silvics of current and desired species,
- sources of reproduction (advanced regeneration, seed, sprouts),
- seedbed characteristics,
- potential competition and control,
- potential damaging agents and control (e.g. herbivory, insects, disease, drought, fire),
- necessary methods (type, sequence, timing, intensity) to successfully establish a new age class of desired species under current conditions.

The cover type chapters provide specific information on sites, silvics, regeneration requirements, and regeneration methods.

Seed germination and seedling development are reliant on various factors such as temperature, light, moisture, nutrient availability, and appropriate seedbed. Site preparation is the practice of altering site conditions to favor the establishment, survival, and growth of desired tree species. The main objectives of site preparation are to prepare a favorable seedbed and control competing vegetation. Site preparation can be accomplished through mechanical means, prescribed fire, use of herbicides, or any combination of these approaches. The timing of site preparation and canopy manipulation is important to consider. Various site preparation methods are described in the artificial regeneration chapter (Chapter 22) of this Handbook.

Stands are successfully established following the initiation of a vigorous new age class of desirable species composition of appropriate size and density (full site occupancy). Maximum seedling numbers occur just before harvest (advance regeneration) or during the first few years after harvest. Stand initiation is completed when the new canopy becomes continuous and trees begin competing with each other for light and canopy space. During the stem exclusion stage, competition among trees is intense and density dependent self-thinning causes significant mortality.

When evaluating stocking levels, it is important to observe seedling species, size, numbers, distribution, damage, and mortality (extent and causes). Stocking surveys are set up systematically by establishing a number of plots throughout the stand. Though it is not necessary to expect 100% full stocking of desirable species, a minimum standard of 70% has been recommended. Desired stocking levels are mentioned in some of the cover type chapters. If adequate natural regeneration is not established by the end of the fourth growing season, then alternative regeneration method should be implemented.

When implementing a stocking survey, consistency in the size and number of sample regeneration plots is important. There are a variety of recommended plot sizes, including:

- 1/1000 acre plot (0.001 acre) having a radius of 3 feet 9 inches
- 1/735 acre plot (0.0014 acre) having a radius of 4 feet 4 inches
- 1/500 acre plot (0.002 acre) having a radius of 5 feet 3 inches
- 1/385 acre plot (0.0026 acre) having a radius of 6 feet 0 inches
- 1/100 acre plot (0.01 acre) having a radius of 11 feet 9 inches

The recommended number of plots to measure in a stand varies; statistical methods should be utilized to determine the most accurate sampling intensity. A common practice is a minimum of one-to-five plots per acre. Before field sampling, plots can be marked to the proper spacing on an aerial photo or map by using a dot grid or some other measuring device.

After the regeneration method is implemented it is important to continue periodic checks to see how the stand is responding. If there are problems with germination or stand development, early detection might help in correcting the problem.

References

British Columbia, Ministry of Forests, Forest Practices Branch. 2001. *Silvicultural Systems Handbook for British Columbia*. For. Pract. Br., BC. Min. For., Victoria, BC.

British Columbia Ministry of Forests and BC Environment. 1995. *Silvicultural Systems Guidebook*. Victoria, BC. Forest Practices Code of British Columbia Guidebook

Forbes, R.D. (editor). 1955. *Forestry Handbook*. Society of American Foresters. New York: Wiley

Helms, J.A. (editor). 1998. *The Dictionary of Forestry*. Society of American Foresters

Kotar, J. 1997. *Approaches to Ecologically Based Forest Management on Private Lands*. Univ. Minn. Extension Serv. NR-604

Marquis, D.A. 1987. *Assessing the adequacy of regeneration and understanding early development patterns*. In R.D. Nyland (Ed.), *Managing Northern Hardwoods*, pp.143-159. SUNY Coll. Environ. Sci. and For., Fac. For. Misc. Publ. No. 13 (ESF 87-002) (Soc. Am. For. Publ. No. 87-03)

Nyland, R.D. 1996. *Silviculture: Concepts and Applications*, McGraw-Hill

Sander, I.L., P.S. Johnson, and R.F. Watt. 1976. *A Guide for Evaluating the Adequacy of Oak Advance Reproduction*. Gen. Tech. Rep. NC-23, USDA Forest Service, North Cent. For. Exp. Stn., St. Paul, MN

Smith, D.M. 1962. *The Practice of Silviculture*, 7th ed. New York: Wiley